Ambo University, School of Graduate Studies, College of Natural and Computational Sciences, Department Of Biology, Environmental Science Stream

Assessment of Agro-Ecology, and Management Practices Effect on Crop Water Productivity of major crops at Dapo Watershed, East Wollega Zone, Oromia Regional State

By: Negasa Bane Biru

A Thesis Submitted To the School Of Graduate Studies of Ambo University in Partial Fulfillment of the Requirements for the Degree of Master in Environmental Science

Major Adviser: Dr. Teklu Erkossa (International Water Management Institute)

Co- advisers : Dr. Esayas Aga (Ambo University, Department of Biology)

: Prof. M. I. Zuberi (Ambo University, Department of Biology)

January, 2013

Ambo, Ethiopia

AMBO UNIVERSITY

SCHOOL OF GRADUATE STUDIES

As Thesis research advisor, I hereby certify that I have read and evaluated this Thesis entitled: Assessment of Agro-Ecology, and Management Practices Effect on Crop Water Productivity of major crops at Dapo Watershed, East Wollega Zone, Oromia Regional State prepared under my guidance by: **Negasa Bane Biru**. I recommend that it can be submitted as fulfilling the Thesis requirement.

--	------------------------	------------------------
Name of Major Advisor	Signature	Date

--	------------------------	-----------------------
Name of Co- Advisor	Signature	Date

--	------------------------	-----------------------
Name of Co- Advisor	Signature	Date

As members of the Board of Examiners of the M.Sc. Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by **Negasa Bane Biru** and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Environmental Science.

--	-----------------------	------------------------
Name of Chairperson	Signature	Date

--	------------------------	------------------------
Name of Internal Examiner	Signature	Date

--	------------------------	------------------------
Name of External Examiner	Signature	Date

Submitted by:

---	------------------------	------------------------
PG Candidate	Signature	Date

Approved by:

--	------------------------	------------------------
Name of Major Advisor	Signature	Date
--	------------------------	------------------------
Name of Co-Advisor	Signature	Date
--	------------------------	-----------------------
Name of Co- Advisor	Signature	Date
--	------------------------	------------------------
Name of Head of Department	Signature	Date
--	------------------------	------------------------
Name of College/Institute Dean	Signature	Date
--	------------------------	------------------------
Name of Director, S/G/Studies	Signature	Date

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my bona fide work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment for the **Degree of Masters of Science, in Environmental Science** at Ambo University and is deposited at the University Library to be made available to borrowers (users) under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic Degree, Diploma, or certificate.

Brief quotations from this thesis are allowed without special permission provided that accurate acknowledgement of source is made. Request for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the college of **Natural and Computational Science** and/or the Department of **Biology** or the School of Graduate Studies when judgment for the proposed use of the material. In all other instances, however, permission must be obtained from the author.

Name: **Negasa Bane Biru** Signature: ___________________.

Place: **Ambo University**

Ambo

Date of Submission: ____________________.

BIOGRAPHICAL SKETCH

The author was born in Gindeberet Woreda, West Showa Zone (Oromia Regional State) Ethiopia, on April 21, 1984. He attended his Elementary and High Schools from 1990 -1998 at Kachisi and Ambo towns, and Ambo Comprehensive Secondary School from 1999 – 2002, respectively.

After completing high school, he joined Hawassa University in 2003, and graduated in July, 2006 with B.Sc. degree in Applied Biology. Soon after graduation, the author was employed by Oromia education bureau in Ambo town administration, West Showa Zone. Since then, he has been working as a Biology Teacher at Ambo High School.

In 2010, he joined the Graduate School of the Ambo University as a candidate for Master of Science Degree in Environmental Science.

ACKNOWLEDGEMENT

First and foremost, I would like to thank Lord God Almighty for giving me the strength and courage to go through all this work. I would like to express how grateful I am to Dr. Teklu Erkossa, my research advisor, Dr. Essayas Aga and Professor M.I. Zuberi my research co-advisers for their remarkable role in giving constructive comments from the very inception of the work and guiding me throughout the study. Their insightful comment for the betterment of the whole work was appreciable. Much credit also goes to the International water Management Institute (IWMI) for granting me the financial assistance needed to complete the study. My special thanks also go to Digga district agricultural office and development agents for their remarkable help during my field work in Digga district and Dapo watershed. I owe an even much debt to my beloved family: my father, step mother, sisters and brothers. My special Thanks to Mrs. Tolossa Kumsa, Egata Sime and their family favorites for their help rendered to me in financial case, my special thanks to Mrs. Alemayew Lamessa (GIS instructor, Ambo University) who helped me in producing map of cropping pattern of the study area. I would like to thank Ambo High School Director, Vice Directors and all staff members especially Biology Department, you all are the greatest blessing in my life, I love you all and thank you very much. I am especially thankful to the farmers of Digga district who responded to my numerous questions with remarkable patience. Finally, all other people who helped me during the study are also acknowledged, may God bless all of you!

DEDICATION

I dedicate this thesis manuscript to my father Bane Biru, and to my Mother Diribe Mamo, for nursing me with affection, love and for their dedicated partnership in the success of my life.

Table of Contents

BIOGRAPHICAL SKETCH iv

ACKNOWLEDGEMENT v

ABSTRACT 1

List of Tables x

List of Annex x

LIST OF ABBREVIATIONS xii

1. INTRODUCTION 2

1.1. Background of the study 2

1.2. Statement of the problem 3

1.3. Objectives of the study:- 3

1.3.1 General Objective: 3

1.3.2 Specific Objectives: 3

1.4. Significance of the study 3

1.5. Scope and limitation of the study 3

1.6. Organization of the thesis 4

2. LITERATURE REVIEW 5

2.1. Roles of water in agricultural sector 5

2.2 Rain fed agriculture in Ethiopia 5

2.3 Agro-ecology and crop productivity 5

2.3.2 Classification of agro-ecology in Ethiopia 6

2.3.3. Major crops grown in agro-ecological zones of Ethiopia 6

2.3.4 Agro-ecology and crop water productivity 6

2.4 Future yield increase and food production from rain fed agriculture. 7

2.5 Tillage and crop productivity 7

2.5.1 Effect of tillage on maize production in Western Ethiopia 7

2.5.2 Effect of tillage on teff production as major crop in Ethiopia 7

2.6 Effect of Crop variety on productivity 8

2.7 Effect of Precursor crops On crop water Productivity 8

2.8 CROPWAT as a tool to study crop water requirement 8

2.8.1 Weather parameters 8

2.8.2 Weather parameters plus crop adaptations 8

3. MATERIAL AND METHODS 10

3.1 Description of the study area 10

3.1.1 Location of Digga district 10

3.1.2 Population of the study area 11

3.1.3 Climate and water availability 11

3.1.4 Topography, Geology and Soils 11

3.2 Land use and farming system 12

3.2.1 Land use 12

3.2.2 Farming system 12

3.3. Land and crop management 12

3.4 Irrigation practices 13

3.5 Data collection 14

3.5.1 Field procedure 14

3.5.2 Mapping of cropping pattern 15

3.6 Monitoring management and performance of crops 15

3.6.1 Selection of plots 15

3.6.2 Estimation of crop water requirement 17

3.7 Data Analysis 17
3.7.1. Descriptive analysis 17
3.7.2 Qualitative analysis 18
4. RESULTS AND DISCUSSION 19
4.1 The Agro-ecologies and the Major crops .... 19_Toc350140123
4.2 Land use land cover of the watershed 20
4.2.1 Forest cover 21
4.2.2 Grass land and bush 21
4.2.3Bush land 22
4.2.4 Grass Land cover 22
4.2.5 Cultivated land 22
4.3 Economic crop water productivity 23
4.3.1 Agro-ecology and crop water productivity 23
4.3.2 Crop type and Economic crop water productivity 25
4.3.3 Crop variety and economic water productivity 26
4.3.4Tillage frequency and Total crop water productivity .... **Error! Bookmark not defined.**
4.3.5 Precursor crop and Economic crop water productivity .... **Error! Bookmark not defined.**
5. SUMMARY CONCLUSION AND RECOMMENDATION 29
5.1. Summary and Conclusion 29
5.2. Recommendations 30
6. Appendixes 31
A. Inputs of FAOCROPWAT model 31
7. References 42

List of Figures

Figure 1: Location map of the study area 10

Figure 2: Cattle night corralling to enhance soil fertility around residence 13

Figure 3: Determination of grain and straw moisture content using oven drying method 16

Figure 4: Map of cropping of the watershed 20

List of Tables

Table 1: Agro-ecologies and major crops grown in the District……………………… ………...14

Table 2: Local areas where sample was taken for study……………………………………...15

Table 3: Agro-ecologies of the study area, and major crops grown…………………………….19

Table 4: land use/land cover types in the Dapo watershed……………………………. ………..21

Table 5: agricultural and non agricultural categories of land……………………………………22

Table 6: Area coverage of the major crops in the watershed…………………………………… 23

Table 7: Grain and straw yield (kg/ha) of Major crops under different Agro-ecologies………...24

Table 8: Crop water productivity respect to agro-ecology……………………………………...25

Table 9: Total Economic crop water productivity (Birr/m3) respect to crop type………………26

Table 10 Crop water productivity respect to crop variety……………………………….. …..27

Table 11: crop water productivity respect to tillage frequency……………………………… …28

Table 12: Crop water productivity relative to Precursor crop………………………………….. 29

List of Annex

Annex1: Table 13, Climate of the area during growing season of 2011………………………..32

Annex2: Table 14, Climate of the area during growing season of 2011……..………………… 33

Annex3: Table 15, Soil characteristics of the study area during growing season……………......34

Annex4: Table 16, Crop water requirement of maize as an example…………………………..35

Annex5: Table 12, Table to collect Data from the district offices and farmers…………………36

Annex6: Table 18, Check list used to measure moisture content of sample…………………….41

LIST OF ABBREVIATIONS

ADLI	Agricultural Development Led Industrialization
AG GDP	Agricultural Gross Domestic Product
AWM	Agriculture Water Management
CC	Climate Change
CWP	Crop Water Productivity
CROPWAT	Crop Water Model
EU	Europe
ET_{act}	Actual evapotranspiration
ET_{pot}	potential evapo- transpiration
FAO	Food and Agricultural Organization
GoE	Government of Ethiopia
GDP	Gross Domestic Product
IPCC	International Panel on Climate Change
LAI,	Leaf Area Index
MDGs	Millennium Development Goals
MoFED	Ministry of Finance and Economic Development
PASDEP	Plan for Accelerated and Sustainable Development to End Poverty
SSA	South and South Asia
SPSS	Statistical Package for Social Science
TDR	Time-Domain-Reflectometry,
USA	United States of America
WPET	Water Productivity Evapo-Transpiration
Yact	Actual Marketable Crop Yield
Y_m	Maximum Yield

ABSTRACT

In Ethiopia food production lags behind while population growth increase, poor management of Soil and Water, poor agronomic practices and environmental degradation are wide spread. In the study area, agriculture depends on rain water; however rain water is not evenly distributed spatially and temporally. The general objective of the study is to assess agro-ecology, and crop management practices effect on crop water productivity of major crops. The specific objectives of the study are: - To identify agro-ecologies of the study area according to local classification system, to map land use type of the rainy season, to identify the crop management practices and to evaluate crop water productivity of major crops across agro-ecologies of the study area.

The methods used for the study are community based survey after brief visit of five days then questioners were prepared to assess the land use of the district, the common rain water management practices, agronomic practices that the farmers use. Field measurement and statistical methods were used to measure physical and economic crop water productivity; different models like Crop Wat.8 and New loc-clim-1.10 were used to assess the crop water requirement and climate of the area.

The result shows that 66% of the watershed is not cultivated while 34% is cultivated. According to local classification system there are three agro ecology zones (Upper zone, Middle Zone and Lower Zone). Middle zone is more productive than lower zone and Upper zone agro ecologies, maize (*Zea mays*) and teff (*Eragrostis teff*) are more productive crops while sesame and niger seed are less productive both physically and economically, improved varieties are more productive than local varieties, maximum tillage frequency in the area is four, increase in tillage frequency increased productivity, and precursor crops affect crop water productivity.

Physical and economic crop water productivity depends on agro ecology, crop type, crop variety, tillage frequency and precursor crops. So less productive agro ecologies need to be managed properly, maize and tef need to be cultivated to get better economic value, improved crop varieties need to be cultivated to get more physical and economic productivity, to some extent increase in tillage frequency is needed and precursor crops need consideration before planting.

1. INTRODUCTION

1.1. Background of the study

Ethiopia is the second most populous country in sub-Saharan Africa, with an estimated population of about 80 million. In order to meet the food needs of this rapidly growing population, the country needs to double its cereal production by 2025 (IWMI, 2005). Agriculture which is mostly based on rain-fed small holder system is the largest sector of the economy contributing about 50 % of the country's GDP and employing over 85% of the population (Rahel Deribe, 2007).

However, rainfall in Ethiopia is characterized by high spatial and temporal variability. Moreover, land degradation mostly soil erosion, deforestation and overgrazing are resulting in declined crop and livestock productivity. The challenge is how to meet the increasing food demand with the degrading natural resource base under worsening climatic conditions and water scarcity. It is important to apply the right agricultural practices and agricultural water management systems in order to increase agricultural water productivity.

Land and water productivity depends on the species of the crops grown, the management practices implemented and the prevailing biophysical environment (Toung,1999). Even within the same species, a variation in cultivars may result in different biomass and marketable products. In addition, crop management, including agronomic practices such as planting dates, seeding rates, cropping systems such as rotation, intercropping, mixed cropping, pest control, as well as soil and water management practices such as tillage frequency and rain water management affect land and water productivity. This study therefore, identified, the land use/land cover, the crop species, crop cultivars and the prevailing management practices in the different agro-ecological zones of the area in order to estimate crop water productivity.

The study has assessed agro-ecology, farming system, attitude of farmers towards new farming methods, the farmers' knowledge about water management systems, constraints and solutions taken by the farmers regarding rain water management techniques.

1.2. Statement of the problem

In Ethiopian, agriculture depends on rain water. However, rain water is unevenly distributed spatially and temporally. In Ethiopia food production lags behind while population growth and poor management of water, poor agronomic practices and environmental degradation are wide spread.

1.3. Objectives of the study:-

1.3.1 General Objective:

The general objective of the study is to study crop production system and there by generate information that can be used by the planners during planning or designing of agricultural related activities.

1.3.2 Specific Objectives:

i. To study crop production methods in the study area

ii. To map the land use type of the study area

iii. To identify the crop management practices in the area

iv. To evaluate water productivity of major crops across agro-ecologies

1.4. Significance of the study

The outcome of this study may serve as a source of additional information for use by farmers, policy makers and planners in design and implementation of good water management and agronomic practices for better crop production and productivity.

1.5. Scope and limitation of the study

This study is based on a cross-sectional data for the time period of 2011/12 aimed at analyzing crop water productivity at Digga District (a relatively high agricultural potential area in the Oromia region). The major limitations of the study relate to the unavailability of secondary data needed to supplement the primary data, so data sources focusing on only a few most important questions were assessed due to resource and time limitations.

1.6. Organization of the thesis

The study comprises five chapters, Chapter one and two deal with introduction and literature review, respectively. Chapter three presents materials and method of the study which is followed by Chapter four presenting the result and discussion, conclusion and recommendation are accommodated in the final chapter.

2. LITERATURE REVIEW

2.1. Roles of water in agricultural sector

Agriculture represents the first traditional life-supporting economic sector closely linked to establish cultural and ethical values of land and water on which traditional societies are built (Einhorn, 2009). According to Appelgren (2004) water is essential input for agricultural production and its linkage to food security and population issues are often reflected in water scarcity and per capita of water availability with finite water resources distributed over growing populations. The global population will continue to grow, though at decreasing rates and is projected to reach around 9 billion by 2050 (FAO, 2009). In general, the growth will occur mainly in the collective population of the developing countries with even a slight decline in population in developed countries. Agricultural water use therefore forms a broad subject that goes beyond producing food, maximizing productivity, improving water use efficiency and protecting the environment. Over two third of the world's food, 83% of the world's cropland is under the rain fed agriculture (FAO, 2009).

2.2 Rain fed agriculture in Ethiopia

Inadequate nutrient supply, depletion of soil organic matter, and soil erosion continue to present serious challenges to crop production in rain fed agriculture in Ethiopia. This is further compounded by increased population pressure that is not accompanied by technological and/or efficiency progress. Efforts by the government to promote the adoption of chemical fertilizers and use of herbicides have been frustrated by escalating prices (Rahel Deribe, 2007).

2.3 Agro-ecology and crop productivity

There is no single way to define agro-ecology, but the concept unifies different groups of scientists, practitioners in the food system, and social movements. According to Altieri, (1995), agro-ecology was defined as the application of ecological systems to agriculture. Twenty years later, agro-ecology was enlarged to the whole food system linking production with the food chain and consumers. Wezel et al. (2009) concluded that agro-ecology means a scientific discipline that questions the dominant agronomic model based on the intensive use of external inputs, the dominant ecological model that separates the protection of biodiversity from the production of food. As such, it proposes an additional new role for farmers as stewards of the landscape and biodiversity.

2.3.2 Classification of agro-ecology in Ethiopia

Agro-ecological zonation is done in different ways in different countries. According to, Dereje Gorfu et al, (2011) in Ethiopia two classification systems are known that include the traditional agro- ecological zones and the elaborated agro-ecological zones developed by MOA and EIAR. The traditional zones include *Bereha, Kolla, Woina Dega, Dega, Wurch* and *Kur* where many kinds of crops are grown in each of these ecological zones.

A major attempt to carry out an agro-ecological zonation for the country was taken up by Mengistu Negash et al. (1989). Principal information for characterizing the major agro-ecological zones (MAZs) and sub-zones was the moisture regime, the thermal regime, and physio-pedomorphic regions of the country. All studies confirm the importance of altitudes above sea level as the primary denominator of agro-ecological zonation.

2.3.3. Major crops grown in agro-ecological zones of Ethiopia

According to Dereje Gorfu et.al, (2011) different crops are adapting to the different agro-ecologies; for example teff is a cool weather crop grown predominantly in the highlands at optimum altitude range from 1800 to 2200 masl while maize and sorghum are common warm weather cereal crops. They are cultivated mostly at lower altitudes along the country's western, southwestern, and eastern peripheries. Now days they are grown between elevations of l500 and 2200 masl and require large amounts of rainfall for good harvests. Among oilseeds sesame grows in warm weather areas unlike, niger seed which grows in the highlands with cool weather.

2.3.4 Agro-ecology and crop water productivity

According to Menale Kassie et.al, (2009) agro-ecology shapes the performance of agriculture in Ethiopia. This implies that the profitability of adopting sustainable agricultural practices will depend on the distribution of rainfall which is affected by agro-ecology and thus this should play a role when formulating policies that promote adoption of productivity-enhancing technologies, such as fertilizers and reduced tillage.

2.4 Future yield increase and food production from rain fed agriculture.

Globally in the past 40 years agricultural land use has expanded 20%–25%, contributing approximately 30% of the overall growth in grain production during the period Ramankutty et.al, (2002). The remaining yield gains originated from intensification through yield increases per unit of land area. However, regional variation is large, as are the differences between irrigated and rain fed agriculture. In developing countries rain fed grain yields are on average 1.5 metric tons per hectare, compared with 3.1 metric tons per hectare for irrigated yields Rose grant et.al, (2002), and increases in production from rain fed agriculture have originated mainly from land expansion. Trends differ by region. Sub-Saharan Africa, with 97% rain fed production of staple cereals such as maize, millet, and sorghum, has doubled cultivated cereal area since 1960, while yield per unit of land has barely changed.

2.5 Tillage and crop productivity

2.5.1 Effect of tillage on maize production in Western Ethiopia

The western part of Ethiopia has a high maize production potential, however, self-sufficient maize production declined and low national average maize yield of 1.7 ton/ha remain stagnant in Ethiopia (Ibrahim and Temene, 2002). The inability to increase yield is attributed to non-sustainable cropping practices, particularly plough or hoe based cultivation (Bzuayehu, 2002). The study of five years (2000-2004) in five selected area of western part of Ethiopia (Bako, Shoboka,Tibe,Ijaji, and Guder) in which three tillage systems (MTRR=Minimum Tillage With Residue Retention, MTRV=minimum tillage with residue removal and CT=Conventional tillage) were used showed tillage systems and concomitant crop residue management significantly affected grain yield (Tolessa Debele, 2007) .

2.5.2 Effect of tillage on teff production as major crop in Ethiopia

Plowing frequency did not affect most of the yield and yield attributes of teff as an example Haftamu Gebretsadik, (2009), but tillering of teff when combined with compaction. Generally, frequent plowing is not a major factor to increase teff productivity on Vertisols but it is important to control weeds. However Fufa Hundera et.al, (2001) reported an “increase in grain yield of teff with an increased plowing frequency” contradicting Haftamu Gebretsadik (2009).

2.6 Effect of Crop variety on productivity

According to Toung, (1999) using improved varieties increase crop water productivity as compared to local varieties. For instance, improved maize varieties represented less than 5% of the maize area in the 1970s accounted for about 60% in 2005 in developing countries. According to FAO, (2005) data, by using improved variety yields of maize increased from as low as 0.88 t/ha in 1971 to over 2 t/ha in 2005 in Niger, with an average growth rate of 2% per year; the area of land sown to maize increased by over 3% annually over the same period due to improvement of productivity.

2.7 Effect of Precursor Crops on Crop Water Productivity

According to Tolera Abera, (2005) precursor crops significantly affect grain and straw yield of crops commonly grown in Bako, Ethiopia. For example maize grown followed niger seed gave grain yield advantage of 20.18% as compared to velvet bean (*Mucuna pruriens).*The low yield of maize following velvet bean *was* due to low residual N because of its poor N-fixation. During crop rotation the depletion of nutrient decreases and straw left from precursor crop is also used as source of nitrogen.

2.8 CROPWAT as a tool to study crop water requirement

CROPWAT is a generic tool that predicts crop water requirements without taking into account the dynamics of and interactions between different processes taking place simultaneously.

2.8.1 Weather parameters

Purely physical phenomena (wind, radiation, rainfall, temperature and relative humidity of the air are integrated through the Penman Monteith equation for ET calculations), can be taken into account directly with CROPWAT, as input parameters (FAO, 1979).

2.8.2 Weather parameters plus crop adaptations

CROPWAT takes into account plant physiology through an internal clock (the unit is in days), which defines the duration of phenological stages, and associates to these stages, crop coefficient values. Changes in two climatic parameters, Temperature and CO2, will modify the growth and development engines of crops through the CROPWAT internal clock (Robina, 2003).

3. MATERIAL AND METHODS

3.1 Description of the study area

3.1.1 Location of Digga district

The study was carried out in Dapo watershed close to Didessa River in Digga District, south-western part of the Abbay River. Dapo watershed is geographically located between 09010’N and $09^0$0’N latitude and 36010’E and $36^0$30’E, longitude (Figure 1). It is approximately 40Km to the west of Nekemte town, the zonal capital of East Wollega zone. Didessa River is one of the major tributaries of Abbay River.

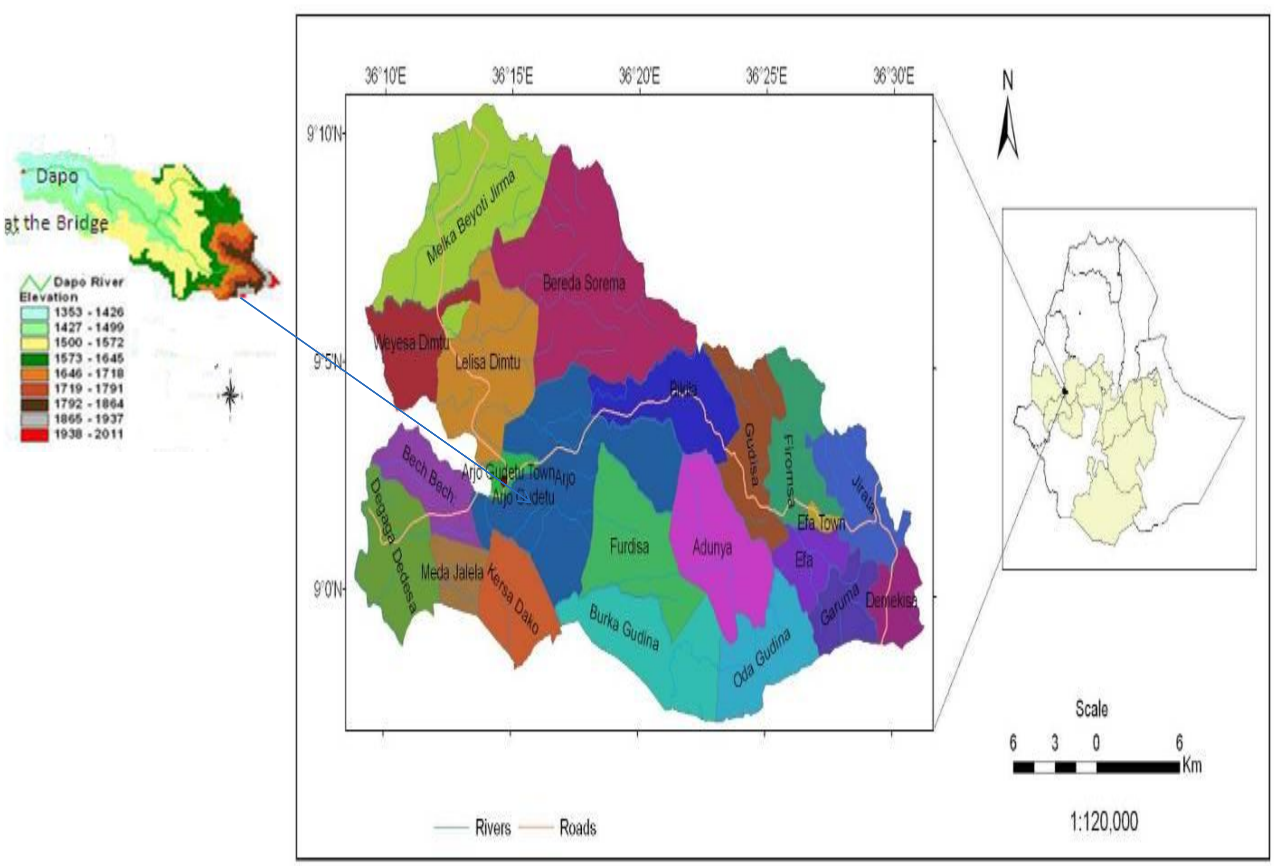

Figure 1: Location map of the study area

3.1.2 Population of the study area

According to Agriculture Bureau, Digga district Accommodates a total population of about 33,695over 90% of which are dependent on Agriculture for livelihood.

3.1.3 Climate and water availability

The Watershed and the surrounding is one of the highest rainfall regions of Ethiopia. Most rivers in the district are perennial but in recent years scarcity of water during the dry season for livestock and people has become an increasingly common phenomenon.

The mean annual rainfall in the area ranges from 1,376 to 2,100mm and has a high annual and inter-annual variability. In some places mean annual rainfall exceeds 2,000mm.The major part of rain is received between end of April and mid of September**.** The annual maximum and minimum temperature varies between 20^0C - 33^0C and 6.5^0C - 19^0C, respectively. Potential Evapotranspiration (PET) in the watershed is generally between 1340 mm -1980 mm per year. PET is higher than 1800 mm/yr, in the lowlands where high temperature is observed.

3.1.4 Topography, Geology and Soils

The altitude of the area varies from 1,200 to 2,342 masl and comprises two agro-ecological zones: the low altitude agro-ecology zone and mid altitude agro-ecology zone. The lowland, bordering the Didessa River, is less steep than the midlands, comprising more rolling terrain.

The dominant soils in the Dapo catchment are Alisols and Acrisols, with some occurrence of Vertisols and Nitosols. However, there is increasing cultivation of the slopes and hence increasing problems of soil erosion and loss of soil fertility. Once the productivity declines too far, farmers simply move on clearing yet more forest, this increases the desperate marginalization of the rural poor which in turn aggravate degradation of natural resources in the area (Brihanu Zemadim, 2011).

3.2 Land use and farming system

3.2.1 Land use

For centuries the watershed and hill plateau have been used for agriculture and grazing land. The major crop is maize followed by sorghum, sesame and finger millet in mid and low altitude agro-ecologies while teff, finger millet, sorghum and niger seed are major crops in representative highland agro-ecology.

The mid altitude agro-ecological zone is steep, formerly forested terrain which is being rapidly cleared of trees. Large areas of forest have been cleared in the last 10 years. Scattered communities tend to cultivate the tops and bottoms of slopes because the slopes themselves are too steep.

In this farming system farmers clear the forest every year to get new fields, thus shifting cultivation is practiced. Mango trees are common especially at lower land agro-ecology as cash crop. Honey bee production for food and market is common in the forest found at eastern part of the watershed. Timber production for home construction and market are common. Coffee cultivation is sparsely distributed.

3.2.2 Farming system

Mixed agricultural is the major livelihood strategy in the study area. In this system crop and livestock production prevails. Rain-fed maize, sorghum, finger millet and teff are the main sources of food in the farming system while sesame and niger seed are mostly grown for market

3.3. Land and crop management

Land preparation is by oxen , while hoe cultivation is common along river banks and on steep hills. Agronomic practices are poorly and variably applied. For example land preparation and planting dates are not dependent on optimum weather condition due to lack of oxen, seed and lack of extension support. Night corralling of live stock is the most common way of maintaining soil fertility in the area(figure 2), but it is limited to backyard only due to fear of cattle thief, The use of crop residues on farm land is also limited by termite attack.

Crop rotation is common but wild animals like monkey that selectively damage some crops like maize and sorghum before and after its maturity, forcing farmers to repeatedly grow them around residents only. This affects crop rotation which in turn affects productivity due to exploitation of nutrients.

There is also mixed cropping practices in the study area that includes: Maize + haricot bean (*Phaseolus vulgaris*), Maize +pumpkin (*Cucurbite maxima*), Maize+ Cabbage (*Birassica oleracea*), Maize + Dinnicha Oromoo (*Coleus edulis*)

Figure 2: Cattle night corralling to enhance soil fertility around residence

3.4 Irrigation practices

Most rivers in the district are perennial but in recent year's scarcity of water during the dry season for livestock and people has become an increasingly common phenomenon which local experts attributed to population pressure, lack of soil conservation measure to reduce erosion, deforestation and overgrazing.

According to Berihanu Zemadim (2011) there is a lot of potential for irrigation, particularly on the flatter terrain of the lowlands. At least 7 of the 31 rivers in the District have the potential to irrigate 300 ha each (i.e. a total of 21,000 ha). In 2009, 1,769 ha has been used / developed under traditional irrigation. Some farmers now have diesel pumps through a government scheme which distributed some 21 pumps. It is possible that up to 330 ha are irrigated with the pumps. On irrigated land, farmers can grow 2 crops per year. In some places, *Bone*, a traditional practice of cultivating in wetland areas using residual moisture, is being undertaken. It is estimated that this is practiced on 1,879 ha in the Diga District. Some farmers have built small ponds and reservoirs, but there seems to be little interest in rain water harvesting due to poor knowledge of rain water harvesting and utilization.

3.5 Data collection

3.5.1 Field procedure

To understand farmers' crop and water management practices and production constraints in the area, survey was conducted using a semi-structured questionnaire. The first step of the field work was brief visits for 5 consecutive days in Digga (24-28, June 2011), which enabled the researcher get an understanding of situation in the District. This was followed by preparation of questionnaire to gather quantitative and qualitative information. After pretesting and improving the questionnaires, the final version was translated into Afan Oromo (Table 17) and implemented. In depth focus group discussions was held in the agro-ecologies.

Information on the agronomic practices such as tillage frequency, rotation plans, amount of seed and fertilizer used, type of cultivars used in the area, whether rain water management practices such as surface drainage, terracing, soil bund, stone bund, grass strip are practiced, were collected by interviewing 15 farmers from each zone . According to the district office there is no highland agro-ecology in the study watershed. So it was not possible to interview all farmers only in the sub watershed, thus interview were held in another area which have an altitude of about 2000-2150m.a.s.l as representative of highland agro-ecology. Fifteen farmers in respect to four major crops from the three representative agro-ecologies (15*3*4=180) farm lands within transact interval in addition to mass interviewing of elders, religion leaders, females and agricultural extension experts.

Table 1: Agro-ecologies and major crops grown in the District

Agro-ecology zone	**Local name**	**Altitude range**	**Major crops Grown**
Low altitude agro-ecology	*Gammoojjii*	<=1450	Maize, sorghum, sesame, finger millet
Mid altitude agro-ecology	*Badda-daree*	1451-2000	Maize, sorghum, finger millet, sesame,
High altitude agro-ecology	*Baddaa*	>=2001	Teff , finger millet, niger seed and sorghum

3.5.2 Mapping of cropping pattern

Cropping pattern of the watershed during the year 2011/12 rainy season was mapped to understand the spatial distribution of the crops and the different land use land cover types. GPS hand set was used for tracking each crop land and other lands found in the watershed, which was later transferred to map source software. The track on the map source was digitized by using dnr Garmin software, and then map was developed using GIS 9.3 software. The Agro-ecologies were extracted based on the local definition system, thus the district office classified the district into three agro-ecologies.

3.6 Monitoring management and performance of crops

3.6.1 Selection of plots

From each agro-ecological zone, four crops that cover at least 70% of agricultural area had been selected and monitored from planting to harvesting dates. These major crops are different at different agro-ecologies according to assessment taken. Five farmers field for each crop was randomly selected from each agro-ecology which makes a total of 60 plots (Table 2).

Table 2 Local areas where sample was taken for study

S.N	Agro-ecology	Association groups(*Got*)	Number of plots	Livelihood strategy
1	Low altitude	Soyoma	4	Mixed farming system
	"	Kachura	4	"
	"	Dapo	12	"
2	Mid altitude			"
	"	Haro	8	"
	"	Bonfata	4	"
	"	Dora	4	"
	"	Soyoma	4	"
3	High altitude			"
	"	Gaba fachase	4	"
	"	Gule juka	8	"
	"	Kaladi fedha Debale	8	"
Total			60	"

The grain and straw yield of the crops was determined by harvesting a quadrant sample using 1m*1m metallic quadrate for maize, sorghum, finger millet, sesame and niger seed, while 20cm*20cm wire quadrate was used for teff and extrapolated to m^2. The fresh weight of the quadrate straw and grain sample was determined by abeam balances. The moisture content of both the straw and grain was determined by oven draining of 100g of subsample at 65^0c for 48 hours (Figure 3). The moisture content was used to adjust grain and straw weight to 12% moisture content which is agronomic standard for storage.

Figure 3: Determination of grain and straw moisture content using oven drying method

3.6.2 Estimation of crop water requirement

The actual amount of water consumed by the crops to produce the observed yield was estimated using the FAO CROPWAT model. CROPWAT 8.0 was used to calculate crop water requirement and irrigation requirement based on average weather data obtained from Didessa and Nekemte weather stations, crop characteristics obtained from field monitoring and the soils of the watershed. To calculate the amount of water consumed by the crops, different inputs are needed in the CROPWAT model these are: Climate /ETo, Rain, crop development stages, and soil characteristics. ETo or climate is calculated by using New-locClim 1.10 model.

Market value of grain and straw was assessed by using market monitoring, and then total economic crop water productivity was determined by dividing total Market value of the products and consumed water in m^3.

3.7 Data Analysis

3.7.1. Descriptive analysis

The quantitative assessment focused on analyzing the descriptive statistics of the data on nature of collective action, characteristics and actual uses of rain water for crop production. Besides the determinants for crop water productivity were analyzed using statistical package for social sciences (SPSS.16) software. Agro-ecology, crop type fertilizers used, agronomic practices like planting date, seeding rate, tillage frequency, and rain water management practices, planting methods were the major independent factors whereas amount of yields produced physical crop water productivity of both grain and biomass, economic water productivity of both grain and biomass were the dependent factors.

3.7.2 Qualitative analysis

In the qualitative assessment, the major livelihood system, types of major crops grown, planting method, types of fertilizer used perceived major constraints to agriculture, common cropping systems, with their constraints and local solutions advantages and disadvantages of using different water management practices were analyzed. The qualitative information was gathered using open ended questions that were included in the questionnaire in order to augment the results of the soil and water management practices that in turn affect crop water productivity in the district.

4. RESULTS AND DISCUSSION

4.1 The Agro-ecologies and the Major crops

According to Dereje Gorfu, (2011) two agro-ecological classifications are known in Ethiopia that include the traditional agro-ecological zones and the elaborated agro-ecological zones developed by MOA and EIAR. Accordingly the traditional classification system is used and there are three agro-ecological zones in the study area, including high altitude agro-ecology *(Baddaa)*, mid altitude agro-ecology *(Badda-daree)* and low land agro-ecology *(Gammoojji)* *(Table 3).*

Results showed that In low and mid altitude agro-ecologies of the major crops grown are maize, finger millet sorghum and sesame, while in high altitude agro-ecology zone teff, finger millet, niger seed and sorghum are dominating.

Table :3Agro-ecologies of the study area, and major crops grown

Agro-ecology zones	Altitude range (masl)	Major crops Grown
Lowland agro-ecology	1200-1450	maize, sorghum, sesame, finger millet
Midland agro-ecology	1451-2000	maize, sorghum, finger millet, sesame,
Highland agro-ecology	2001-2350	teff , finger millet, niger seed and sorghum

4.2 Land use land cover of the watershed

By using GPS tracking method the cropping pattern of 2011/12 cropping season was identified and the following map was developed. From the map, land use type and the major crops are shown on (Figure 4) with their respective area coverage (Table 4).

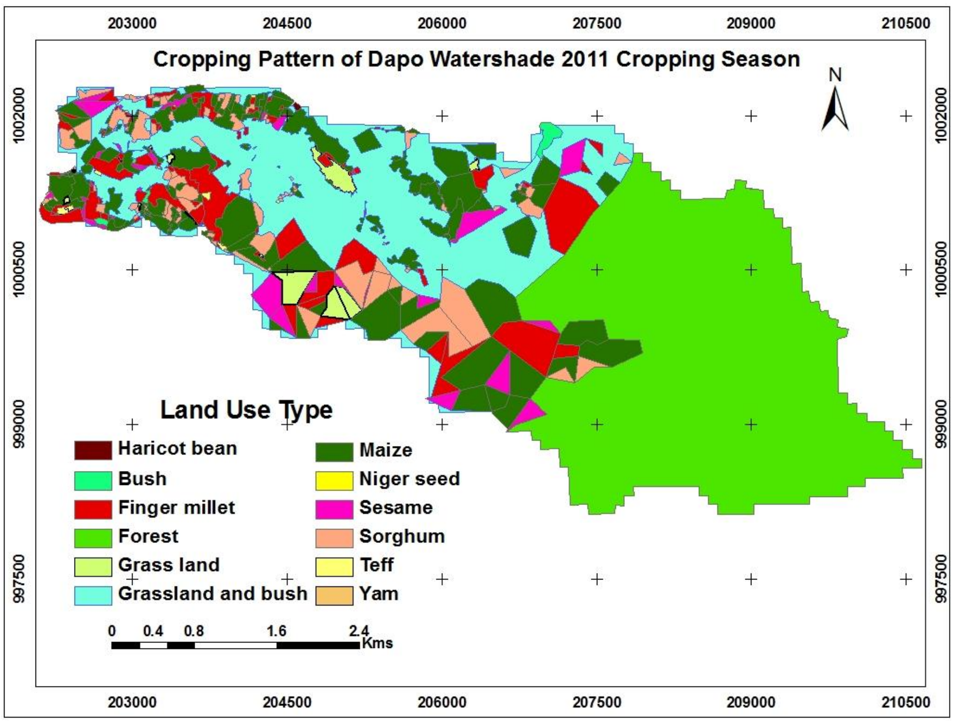

Figure 4: Map of cropping of the watershed

Table: 4 land use/land cover types in the Dapo watershed

Land use Type	Area (ha)	%
Forest	796.26	43.18
Grassland and bush	391.29	21.22
Maize	315.19	17.10
Finger millet	142.64	7.74
Sorghum	108.78	5.99
Sesame	52.47	2.85
Grass land	29.299	1.59
Bush	5.30	0.29
Teff	1.94	0.11
Haricot bean	0.69	0.04
Niger seed	0.27	0.01
Yam	0.01	Nill
Total	1844.13	100

4.2.1 Forest cover

Covering about 43% of the water-shed area, the major part of the forest land lays at the eastern part of Dapo watershed. The forest is a source of timber production for construction and hosts traditional hives. The forest is kept since it is marginal to agriculture and sources of wild coffee.

4.2.2 Grass land and bush

This land unit is the second dominant land cover in the study area covering an area of 21.2% of the water-shed. It is mixed with cultivated land and dominantly found at mid and lower part of agro-ecological zones due to shifting cultivation. It is characterized by short stem trees with dense grass cover. The grass land is used for grazing while bush lands are used as source of fire wood.

Table: 5 agricultural and non-agricultural categories of land

Land use type	Area (ha)	%
Agricultural land	621.28	**34**
Nonagricultural land	**1222.85**	**66**
Total	**1844.13**	**100**

4.2.3Bush land

This represents a degraded shrub land which is characterized by degraded land covered small trees and with no grass cover. This land unit is mainly found at the lower part of the local area called Haro. This land cover/use covers only an area of 0.29% of the study area and is used as source of fire wood.

4.2.4 Grass Land cover

This land cover type is characterized by an area covered by open grassland. It is mostly used for grazing purpose. Mostly located at the middle part, the grass cover occupies an area of about 1.60% of the watershed.

4.2.5 Cultivated land

This land cover type is dominant next to forest accounting for 33.73% of the watershed area. This land use land cover type spread over the three agro-ecological zones, with different crops dominating in each zone. The crops commonly grown in the highland(*Baddaa*) part are teff, finger millet, sorghum, niger seed etc, In mid land (*Badda-daree*) and low land (*Gammoojjii*) agro-ecological zones, the crops most commonly grown include maize, sorghum, finger millet and sesame . Even though secondary data of the district shows sorghum is dominant next to maize the result of map shows that maize is the dominant crop followed by finger millet, sorghum and sesame respectively.

Table 6 Area coverage of the major crops in the watershed

Crop Type	Area (ha)	%
maize	315.19	50.73
finger millet	142.64	22.96
sorghum	108.77	17.51
Sesame	52.47	8.45
Teff	1.94	0.31
Niger seed	0.27	0.04
Total	621.28	100

4.3 Economic crop water productivity

4.3.1 Agro-ecology and crop water productivity

According to Menale Kassie (2009) agro-ecology shapes the performance of agriculture, production and productivity in deferent agro-ecologies. According to Dereje Gorfu (2011) different crops are adapting at different agro-ecologies for example Teff is a cool weather crop grown predominantly in the Ethiopian highlands at optimum altitude range of 1800 to 2200m asl while maize and sorghum are a common warm weather cereal crop widely grown in Ethiopia. So these crops are more productive in agro-ecology where they are adapting.

The result of this study shows that there is a significant difference between the different agro-ecological zones in terms of water productivity. Accordingly in Dapo watershed crop production and crop water productivity was the highest in the mid altitude agro-ecology or (*Badda-daree*), followed by low altitude agro-ecology (*Gammojjii*) and the least was at high altitude agro-ecology (*Baddaa*). This may be due to exploitation of the highland and lowland agro-ecology zones by over population. This explains seasonal migration of people from the highlands to cultivate crops in the mid and lowland agro-ecologies beside resource scarcity such as land in the former.

Table 7: Grain and straw yield (kg/ha) of Major crops under different Agro-ecologies

Crop Type	Yield($kgha^{-1}$	Low Altitude	Mid altitude	High Altitude
Maize	Grain	4520	4648	-
	Straw	12724	13702	-
Sorghum	Grain	2350	2556	642
	Straw	7616	10172	3648
Finger millet	Grain	1292	1410	1034
	Straw	4426	3190	5865
Sesame	Grain	536	535	-
	Straw	2220	2360	-
teff	Grain	-	-	1806
	Straw	-	-	14893
Niger seed	Grain	-	-	239
	Straw	-	-	1434

As shown from above (table 7) the physical grain and straw production of different crops is high in mid altitude, medium in low altitude and less in high altitude. This shows that the physical production of the grain and straw varies within the variation of Agro ecology.

Table 8: Crop water productivity respect to agro-ecology

Agro-ecology	Crop WP (kg/m^3) with respect to effective rain	Economic crop WP of Grain ($Birr/m^3$)	Economic WP of straw ($Birr/m^3$)	Grain WP (Kg/m^3) res consumed water	Total economic WP ($Birr/m^3$)
Upper zone	0.20	2.97	1.10	0.50	4.10
Middle zone	0.28	3.66	1.80	0.70	5.50
Lower zone	0.29	3.27	1.85	0.70	5.11
Total	0.26	3.30	1.58	0.63	4.90

As shown from the above (table 8), the total economic crop water productivity varies with variation in agro ecology for instance middle zone(5.50 $birr/m^3$) is the highest while the upper zone (4.10$birr/m^3$) is the least .This shows that across the agro ecology there is a deference in total economic crop water productivity.

4.3.2 Crop type and Economic crop water productivity

Different crops perform differently in water consumption efficiency which in turn affects productivity (Robina et.al 2003) for example maize is the most water efficient crop in semi-arid areas. As shown in table 10, maize is the most productive while niger seed is the least productive respect to consumed water.

Table: 9 Total Economic crop water productivity (Birr/m3) respect to crop type

crop type	Crop WP (kg/m^3) with respect to effective rain	Economic WP of Grain ($Birr/m^3$)	Economic WP of straw ($Birr/m^3$)	Grain WP (Kg/m^3) respect to consumed water	Total economic WP ($Birr/m^3$)
Maize	0.56	5.03	3.55	1.44	8.58
Sorghum	0.21	2.46	1.38	0.47	3.84
Sesame	0.10	2.1	0.21	0.20	3.20
Finger millet	0.21	2.58	2.12	0.48	4.71
Teff	0.53	7.31	0.86	1.32	8.17
Niger seed	0.05	1.07	0.10	0.09	1.18
Total	0.26	3.30	1.58	0.63	4.88

As shown from (Table 9) crop water productivity of maize and teff is the highest while niger seed and sesame are less productive, So crop type affects physical and economic crop water productivity.

4.3.3 Crop variety and economic water productivity

According to Toung, (1999) using improved varieties increase crop water productivity in developing countries as compared to local varieties. According to (FAO 2005) data, by using improved variety yields of maize increased from as low as 0.88 t/ha in 1971 to over 2 t/ha in 2005 globally. As Shown on the following (table10) the total economic crop water productivity varies with the variation in the crop variety for instance improved varieties are more productive (9.76 birr/m3) than local varieties (4.4 Birr/ m3). Accordingly, improved varieties are more productive than local varieties, corroborating (Toung 1999).

Table:10 Crop water productivity respect to crop variety

Crop Variety	Crop WP (kg/m^3) with respect to effective rain	Economic crop WP of Grain ($Birr/m^3$)	Economic WP of straw ($Birr/m^3$)	Grain WP (Kg/m^3) respect to consumed water	Total economic WP ($Birr/m^3$)
Improved Variety	0.62	6.43	3.33	1.50	9.76
Local variety	0.23	3.01	1.42	0.55	4.4
Total	0.26	3.30	1.60	0.63	4.88

Mean tillage frequency	Crop WP (kg/m3) with respect to effective rain	Economic crop WP of Grain (birr/m3)	Economic straw WP of straw (birr kg/m3)	Grain WP (Kg/m3) with respect to consumed water	Total Economic WP (birr/m3)
1	0.07	2.28	0.15	0.17	2.44
2	0.24	3.05	1.51	0.58	4.56
3	0.26	2.74	2.22	0.64	4.95
4	0.39	5.06	1.55	0.93	6.61
Total	0.26	3.23	1.58	0.63	4.88

Table 13 Crop water productivity respect to tillage frequency

precursor crop	Physical Crop WP (kg/m^3) with respect to effective rain	Economic crop WP of Grain ($birr/m^3$)	Economic WP of straw ($birr/m^3$)	Physical Grain WP (Kg/m^3) with respect to consumed water	Total Economic WP ($birr/m^3$)
fallow	0.36	4.21	1.85	1.14	6.07
non legume but different	0.37	6.06	1.68	0.73	7.74
non legume but same	0.24	3.03	1.54	0.56	4.57
Total	0.26	3.30	1.58	0.63	4.88

5. SUMMARY CONCLUSION AND RECOMMENDATION

5.1. Summary and Conclusion

This study focused on assessment of agro-ecology, agronomic and management practices effect on crop water productivity of Major Crops Grown, Such as: maize, sorghum, finger millet, sesame, teff and niger seed at Digga district Dapo watershed, east wollega zone Oromia regional state.

The area of the watershed is approximately $18km^2$ which ranges between altitude of (1345-2011) masl and is classified in to two agro-ecological zones according to Local classification system, these are low altitude agro-ecology zone (1200-1450masl) and Mid altitude agro-ecology (1451-2000masl). The areas of major crops obtained through watershed Tracking of maize, finger millet, sorghum and sesame are 315.19 ha, 142.64 ha 108.77 ha, 52.467 ha respectively.

The SPSS data analysis shows that Crop water productivity depends on different determinant factors these are agro-ecology, crop type, crop variety, planting date, planting method, seeding rate, tillage frequency, and Precursor crop are affecting the crop water productivity positively. The total economic crop water productivity of the mid altitude (5.47 birr/ m^3) is the most productive area followed by Low altitude (5.12 $birr/m^3$) and High altitude (4.05 birr/

m^3) respectively. The mid altitude and low altitude are relatively similar while high altitude agro-ecology is less in productivity.

Crop types also affect total economic crop water productivity, accordingly productivity of maize is (8.6 birr/m3) followed by Teff (8.17 birr/ m^3), Finger millet (4.71birr/ m^3) ,sorghum (3.83 birr/ m^3) ,sesame (3.20 birr/m m^3),Niger seed(1.17birr/m m^3). So maize is most productive while Niger seed is the least in productivity. The same crop with different cultivars also vary in total crop water productivity that is improved variety (9.76 birr/m m^3) is more productive than local variety (4.43 birr/m m^3). Precursor crops also affect crop water productivity, i.e. plot followed by non legume but different crops (7.73 birr/m3) is more productive than followed by fallow land (6.06 birr/m m^3) and non legume but same crops (4.57 birr/m m^3).

5.2. Recommendations

Since Crop water productivity depends on different factors these factors have to be managed properly for instant the high altitude agro-ecology zone is less productive so it must be managed properly in case of soil and water conservation. Low land agro-ecology is also exploited since it is near to infrastructure and far from forest from which wild animals like monkey destructs their crops also must be conserved well.

Since total economic crop water productivity is also depend on different factors these factors must be well managed for example crops types like maize and teff must be cultivated since they are high in economic productivity, improved crop variety must be adapted in the area since improved varieties are more productive than local varieties. Tillage frequency also affect crop water productivity so the lands must be ploughed more since the surface area of soil increases and that is increasing the absorption of nutrients by the crops. The farm lands must be shifted yearly by different crops since the exploitation of nutrient decreases nutrient due to lack of shifting cultivation.

Future research:

This study needs to be continued to include the following points for the future. The result of this study is based on the survey of the area and monitoring which is based on the response of the farmers in the area so further studies that is experimental must be take to get best results and scaling up the appropriate findings to the other area of the same agro-ecology zones. Even though application of fertilization and productivity is positively related, in this finding it is negatively correlate so further research is needed.

6. Appendixes

A. Inputs of FAOCROPWAT model

Table 13: Climate of the area during growing season of 2011

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	11.6	25.7	56	95	7.9	19.2	3.68
February	12.3	26.7	52	104	7.7	20.1	4.09
March	13.0	27.0	64	112	7.4	20.7	4.21
April	13.3	26.7	55	104	7.1	20.4	4.31
May	12.8	24.3	68	69	5.6	17.7	3.49
June	11.5	21.7	87	69	4.2	15.3	2.79
July	11.1	20.7	93	104	3.3	14.1	2.46

August	11.0	20.7	95	69	3.3	14.4	2.49
September	10.6	21.8	84	69	4.3	15.9	2.82
October	11.3	23.2	74	104	6.7	18.8	3.39
November	12.0	24.2	65	104	7.3	18.5	3.48
December	11.6	24.7	60	104	7.3	17.9	3.44
Average	11.8	23.9	71	92	6.0	17.8	3.39

Table 14:Climate of the area during growing season of 2011

	Rain	Effective rain
	mm	mm
January	8.0	7.9
February	16.0	15.6
March	60.0	54.2
April	85.0	73.4
May	233.0	146.1
June	380.0	163.00
July	422.0	167.2
August	367.0	161.7
September	294.0	154.4
October	142.0	109.7
November	60.0	54.2
December	22.0	21.2
Totl	2089.0	1128.8

Table 15:Soil characteristics of the study area during growing season

Average soil name:	silty loam
Total available soil moisture(FC-WP)	190mm/meter
Maximum rain infiltration rate	277mm/day
Maximum rooting depth	Depend on crop type in centimeter
Initial soil moisture depletion(as %TAM)	14
Initial available soil moisture	163mm/meter

Table 16: Crop water requirement of maize as an example

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.30	1.30	1.3	2.1	1.3
Apr	2	Init	0.30	1.32	13.2	22.0	0.0
Apr	3	Init	0.30	1.23	12.3	30.9	0.0
May	1	Deve	0.30	1.13	11.3	42.4	0.0
May	2	Deve	0.41	1.44	14.4	51.3	0.0
May	3	Deve	0.60	1.94	21.3	52.3	0.0
Jun	1	Deve	0.78	2.35	23.5	52.8	0.0
Jun	2	Deve	0.95	2.65	26.5	54.9	0.0
Jun	3	Mid	1.11	2.97	29.7	55.2	0.0
Jul	1	Mid	1.13	2.91	29.1	55.5	0.0
Jul	2	Mid	1.13	2.78	27.8	56.1	0.0
Jul	3	Mid	1.13	2.79	30.7	55.4	0.0
Aug	1	Mid	1.13	2.81	28.1	54.5	0.0
Aug	2	Mid	1.13	2.82	28.2	53.9	0.0
Aug	3	Late	1.10	2.85	31.4	53.1	0.0
Sep	1	Late	0.92	2.49	24.9	53.4	0.0
Sep	2	Late	0.73	2.06	20.6	53.2	0.0
Sep	3	Late	0.55	1.64	16.4	47.7	0.0
Oct	1	Late	0.40	1.27	7.6	25.1	0.0
Total					398.3	871.9	1.3

Table 17: Table to collect Data from the district offices and farmers

Area coverage of the major crops grown in different agro-ecologies

Crop type	Maize		Sorghum		Sesame		Finger millet	
Agro-ecology	Area(ha)	%	Area(ha)	%	Area(ha)	%	Area(ha)	%
High altitude								
Mid altitude								
Lowland								

Checklist for assessing crop Management practices

Name of Watershed

Position in the landscape (upper, middle**,** lower)

Location (*Lat*= *long*=*alt*=)

Household head's Name:-

Agro-ecology	Altitude range (masl)	Area(ha)	Major livelihood strategy	Remark
Highland				
Mid altitude				
Low Land				

I. **Major crops grown**:

crop	Soil type	Area allocated (ha)	Variety Name*	Planting Date	Seeding Rate (kg/ha)	Planting method	Fertilization Used (yes/no)	Harvesting date

*Name of commercial improved varieties or local

II. Input used for the major crops

crop	Type and quantity of fertilizer applied(kg/ha)						Major constraints perceived	Biomass (kg/ha)	Grain (kg/ha)
	N		P		Compost/ Manure				
	Rate	Date	Rate	Date	Rate	Date			

III. Common cropping systems

A crop rotation practiced (yes/no), If yes show pattern

B .Relay cropping practiced (yes/no) if yes, show sequence

Options	Crop 1	Crop 2	Crop 3	Crop 4
1				
2				
3				
4				
5				

C. Mixed cropping

Main crop	Secondary crops		
	1	2	3

A. Water related constraints with respect to the major crop fields and suggested solutions obtained from farmers

Crops	**Major constraints**	**Suggested solutions**

B. opinion of farmers about some suggested rain water management alternatives

Rain water mgt. practices	Pros	cons
RWH ponds		
Terraces		
Soil bund		
Stone bund		
Surface drainage		
Grass strip		
Soil fertility enhancement		
New crop species		
New crop varieties		
Appropriate planting date		
Appropriate plant population		
Land use change		
Supplemental irrigation in the rainfed system		

C. Management system of soil in the area

Rain water mgt. practices	Pros	cons
RWH ponds		
Terraces		
Soil bund		
Stone bund		
Surface drainage		
Grass strip		
Soil fertility enhancement		
New crop species		
New crop varieties		
Appropriate planting date		
Appropriate plant population		
Land use change		
Supplemental irrigation in the rainfed system		

IV Water management

a. Identify Water related constraints with respect to the major crop fields and suggested solutions

Crop	**Major constraints**	**Suggested solutions**

Data record sheet for the focused crop monitoring

Monitor 5 to 10 plots each of the top 3 to 4crops that cover at least 70% of the area landscape position (upper, middle, low)

Crop type	variety	Planting date	Seeding rate	Plant population Count	Land cover (%) estimate		Days to flowering	Days to maturity
					Seedling Rate	Max. Canopy cover		

Continued from above

Crop	Type and quantity of fertilizer applied (%)						RWM	Bioma ss (kg/ha)	Grain (kg/ha)
	N		P		Compost (manure)				
	Rate	Date	Rate	Date	Rate	Dat e			

Table 18: **Check list used to measure moisture content of sample**

Farmers name	Major crops	Mass in gm at harvest		Harvested Date	Population Per m^2	Location		Agro-ecology	Mass put in oven		Mass after oven dry in gm		Moisture lost In gm	
		Yield	B mass			Northing	Easting				crop	Biomass	crop	Biomass

7. References

Altieri M A., 1995. Agro-ecology: The Science of Sustainable Agriculture. West view Press, Boulder.

Bajwa, R.,N.Aslam and A.Javaid .,2000.Comparsion of three green manures for growth andVA mycorrhizal colonization in maize (Zea mays) online J.Biol.,Sci.,2:512-517

Bezuayehu,T. Gezahenn,A Poulos, D.& Jabbar,M.A.,2002. Nature and cause of land degradation in the Oromia region: A review socio economics and policy research working paper No.36, ILRI, Addis Abba

Birhanu Z., 2011 Integrated Rain Water Management Strategies in the Blue Nile Basin of the Ethiopian Highlands

Appelgren. 2004. Water and agriculture, the United Nations Educational, Science and Cultural Organization, France

Dereje Gorfu, 2011. Agro-ecologies of Ethiopia and major crops grown; collaboration with EIAR.

FAO 2005, FAOSTAT: FAO statistical databases. Rome: Food and Agriculture Organization of the United Nations.1998

FAO, 2009. How to feed the world in 2050, Issue brief from the High-Level Expert Forum held in Rome, 12-13 October FAO, Rome, Italy.

Fufa Hundera., Tesfaye Bogale., Hailu Tefera., Kebebew Asefa., Tiruneh Kefyalew., Abbera Debelo & Seifu Ketema, 2001. Agronomy Research in Teff. In: Hailu Tefera, Getachew Belay & M. Sorrels (eds.), Narrowing the Rift: Teff Research and Development. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia, pp.167-176.

Haftamu Gebretsadik., 2009. Tillage Frequency, Soil Compaction and N-Fertilizer Rate Effects on Yield of Teff (Eragrostis Tef) in Central Zone of Tigray, Northern Ethiopia Mekele university Mekele.

Ibrahim,M. & Tamene,T., 2002. Maize technologies: Experience of ministry of Agriculture.In N.Mendefiro, D.Tanner and S.Twumasi-Afriyie(eds).Prociding of the second national maize work shop of Ethiopia,Addis Ababa

IWMI Working Paper 98, Experiencing and Opportunities for Promoting Small scale/ Micro Irrigation and Rainwater Harvesting for Food Security in Ethiopia, IWMI, 2005.

Menale Kassie, 2009 Sustainable Agricultural Practices and Agricultural Productivity in Ethiopia.

P.Einhorn,2009. Water and Agriculture Implications for Development and Growth Essays of Water Conference Center for Strategic and International Studies 1800 K Street, N.W., Washington, D.C. 2009.

Rahel Deribe 2007. Institutional analysis of water management on communal irrigation systems in Ethiopia: the case of atsbi wemberta, Tigray region and Ada'a woreda, Oromia region Addis Ababa.

Ramankutty, N., J.A. Foley, and N.J. Olejniczak. 2002. "People and Land: Changes in Global Population and Croplands during the 20th Century." Ambio 31(3): 251–57.

Robina Wahaj.,2003 ACTUAL crop water use in project countries: a synthesis at the regional level

Rose grant,Met. 2002. "The Role of Rainfed Agriculture in the Future of Global Food Production." EPTD Discussion Paper 90. International Food Policy Research Institute, Environment and Production Technology Division, Washington, D.C.

Tolera Abera., 2005. Influence of precursor crops on in organic Fertilizer response of maize at Bako, Pakistan journal of Biological science

Tolessa Debele, C.C.Du Preez and G.M.Ceronio, 2007, Effect of tillage system and nitrogen fertilization on yield and yield components of maize in Western Ethiopia, university of the Free State, South Africa

Tuong, T.P., 1999. Productive water use in rice production: opportunities and limitations. J. Crop Prod. 2, 241-264.

Wezel A,Peng, 2009 Agro-ecology as a science, a movement and a practice. A review. Agronomy for Sustainable Development 29, 503-515

World Bank 2001, World Development Indicators 2001,CD-ROM, The World Bank Washington DC.

Zwart S.J. and Bastiaanssen W.G.M., (2004), Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize, Agricultural Water Management, 69(2), 115-133.